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U.S. Forest
Service

TUBED SEEDLING PROGRAM IN REGION NINE: A SUMMARY

U.S.D.A. Forest Service

A SUMMARY
OF THE
TUBED SEEDLING PROGRAM
IN REGION NINE

U.S.D.A. FOREST SERVICE

July 1968

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TUBED SEEDLINGS

INTRODUCTION

The idea of growing seedlings in pots or tubes is by no means new. There have been many methods presented varying from placing seedlings in tar-paper pots to growing the seedlings in containers. Results were considered unsatisfactory and there was insufficient interest generated until the results of recent Canadian research. Based on Canadian experiences and research, pilot plant operations were started in Region 9 to determine possible use of the tubed seedlings. The procedures reported here were based almost entirely on the pioneering work done in Ontario, Canada.

Canadian Experiences 1/

In 1957 the Ontario Department of Lands and Forests, Division of Research, conducted trials to assess the feasibility of using tubed seedlings. These trials showed that the seedlings could survive, and in 1958 a formal experiment was designed to determine whether the technique could be used during the summer months as well as the regular spring and fall planting seasons. These tests showed that the seedlings planted during the summer have satisfactory survival at the onset of winter.

1/ Reference material:

1. Experimental Planting of Tubed Seedlings, 1958 by M. M. McLean, Ontario Department of Lands & Forests, Division of Research, Report No. 39, May 1959.

2. Preparation and Planting of Tubed Seedlings by V. H. H. Williamson, Ontario Department of Lands & Forests, Division of Research, Report No. 52, January 1964.

The tests also indicated a significant difference in survival percentage between fall and summer plantings and between screened and unscreened plots. The differences between the screened and unscreened plots were not due to protection against birds and animals but rather to the changes in the seedlings' environment under screens.

In 1963 a development program was initiated for the purpose of preparing the tubed seedlings for field use. There were still many problems covering the best material, planting tools, and the equipment needed for preparing the tubes. The resulting equipment and procedures made it possible for one man to prepare tubes, load them with soil, add seed and place them in germination flats at the rate of 1,200 per hour.

The production of tubed seedlings, or tubelings as they are often called, requires the use of greenhouses for control of temperature, humidity, and air circulation. The Canadians have developed and are using plastic portable greenhouses. Each unit which is 12'x34' is heated by a 45,000 BTU gas burner and will hold about 426 trays or 86,000 tubes. The number of greenhouses needed is governed by the species and size of the program. The species is a factor due to the time required in the greenhouse. For example, spruce requires 7 weeks while red pine requires 4 weeks. The 86,000 is about 50 man-days of planting. The losses in the greenhouses have been about 20%--contributed to germination 8%, improper loading 7%, and losses from heat, etc. 5%. In addition, there is a small loss in tempering when the seedlings are taken out of the greenhouse and placed under shade in the nursery. It is advisable that the root growth not extend outside of the tube and the Canadians are coating the trays with a copper solution to get this control.

Production costs for F.Y. 1967 for tubed seedlings were $13.00 per M which includes the cost of writing off the greenhouses on a total 24MM program. They expect to reduce costs to about $8.00 per M.

All planting is done on prepared sites. On sites with low herbaceous cover the area is first burned and then scarified. The planting tool is a dibble on the end of an ordinary garden hoe. The hoe is used to refine the planting spot and the dibble which has a guide for a fixed depth prepares the hole. In firm soil the tube is placed level with the ground line while in loose soil the tube projects to a maximum of one inch above the ground line. It was originally planned to use a special tool for planting, but it was found that the mortality was very high because the soil was not compact around the tube. By placing the tube by hand it was very easy to firm the soil around the tube with the fingers.

Seedling survival after one year varied from 50 to 80 percent. Frost heaving has been the principal cause of mortality and in some cases the tube was ejected from the soil. This has proven that the tube must be placed in a selected spot to give maximum protection and that it is possible to overscarify.

To date it appears that the big advantage is in extending the planting season through the summer months.

Region 9 Experiences

Through close contact with the Ontario Department of Lands and Forests, Division of Research, we had been appraised of the research that the Canadians were doing with tubed seedlings. In March 1966 a trip was

made to Maple, Ontario, Canada to become better informed and if possible gather sufficient data to justify pilot trials.

Observations, plus the Ontario plans for a 40MM program during C.Y. 1966, was considered a sufficient basis for starting trials and an order was placed for the necessary equipment and supplies. The size of the Ontario program placed a heavy demand on the manufacturers and equipment was received too late to start the trials. An order was then placed for additional tubes and a 300M trial program was set up for C.Y. 1967. The program consisted of 150M red pine on the Superior and 150M spruce on the Ottawa.

The tubed seedlings were produced at the Eveleth and Toumey Nurseries using the greenhouses developed for the tree improvement grafting program. The techniques developed by the Ontario Department of Lands and Forests were followed except that we used a special peat which was fumigated to control weeds and prevent damping-off.

The red pine was kept in the greenhouse for three weeks followed by one week of hardening-off-outside in the nursery. A plastic screen was used to provide about 50 percent shade and protect the seedlings from driving rains. Greenhouse culture is necessary for development of early planting stock, but it is possible and we have had very good success in producing stock outside for use after late July. The trays were loaded in the regular way and set outside in beds under a plastic shade screen.

The spruce tubed seedlings produced at the Toumey Nursery required about ten weeks to develop. No attempt was made to grow them outside of the greenhouse, but there is a good possibility of doing so.

Planting of the tubelings started in early June and continued into September. The sites varied considerably as did the type of ground preparation. The hoe with dibble was used for all planting. A burn which took place the first week in June was planted a week later without any additional ground preparation. This proved to be ill advised as the survival was under 50 percent. With ground preparation and more attention to selection of the spot to place the tubeling the survival might have been 80 percent or more. Going into the winter the survival, outside of the burn, was very satisfactory. The governing factor will be the overwinter survival. If the spring check is satisfactory, we plan to work tubed seedlings into the Region's reforestation program.

OBJECTIVES

The objectives of the tubed seedling program are:

(1) To develop a more efficient method of producing seedlings and reforesting timber lands.

(2) To develop reforestation methods that will extend the planting season.

(3) To provide planting stock that can be produced on short notice for an emergency program.

EQUIPMENT AND MATERIALS

Greenhouse

The greenhouses being used at the Eveleth and Toumey Nurseries are those developed for the tree improvement program. General description:

Plastic greenhouse, Gro-Mor (Lord & Burnham)

Size - 22'x48'

Modine gas-fired heaters

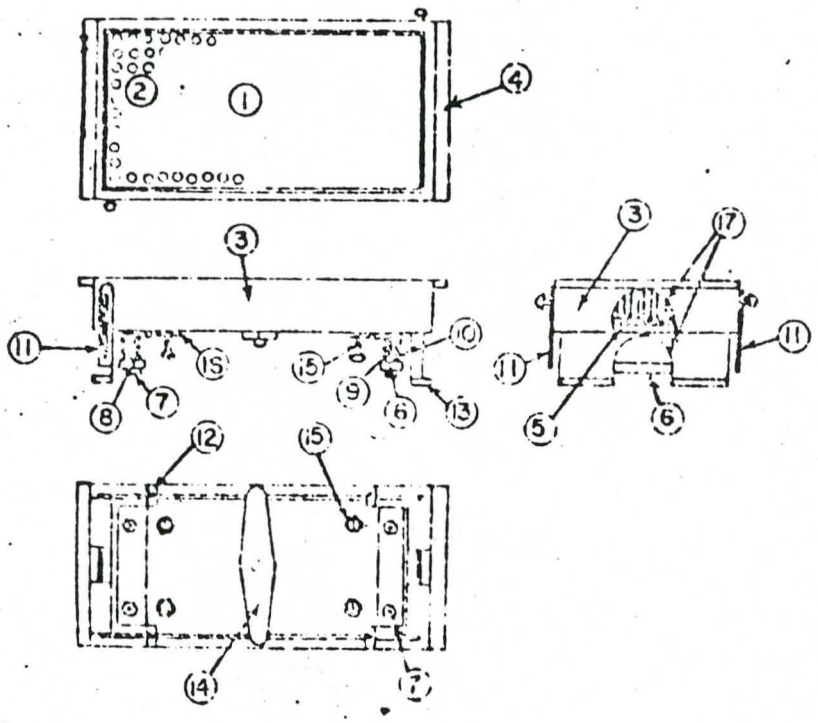
Ventilating tube - 18" diameter

Ventilating fan - Acme - 2-speed - 24"

Estimated cost w/o side walls - $4,000

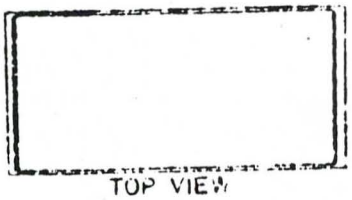
Tube Loading Machine (Designed by Ontario Department of Lands and Forests)

TUBE LOADING MACHINE

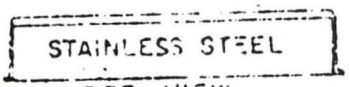


PARTS

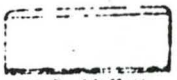
1 DOWEL TABLE
2 DOWELS
3 LOADER SIDES
4 SIDE HANDLES
5 TUBE CLEARING PLATE
6 THUMB BARS
7 THUMB BAR ANCHOR NUTS
8 THUMB BAR LOCKING NUTS
9 PUSH RODS
10 PUSH ROD SPRINGS
11 SIDE DROP GUIDE
12 SIDE STOP LUGS
13 OFF-SET FEET
14 SIDE LOCKING BAR
15 SPACE ADJUSTING SCREWS
16 SPACE ADJUSTING SCREW LOCK-NUTS
17 SEMI-CIRCULAR CUT-OUT


TOP VIEW

SOIL RETAINING FRAME



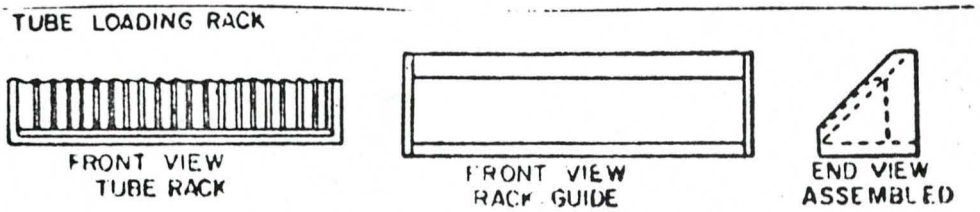
SIDE VIEW


END VIEW

Approximate Cost - $100.00

Manufactured by: Atlas Engineering & Machine Co., Ltd.
16 Eastern Avenue
Toronto, Ontario, Canada

Tube Loading Rack - used with the loading machine



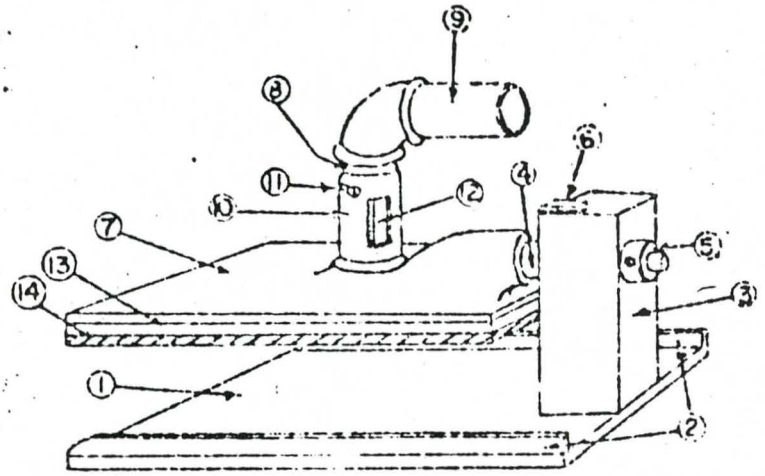
Approximate Cost - $10.00

Manufactured by: Redirack Industries, Ltd.
114 Clayson Road
Weston, Ontario, Canada

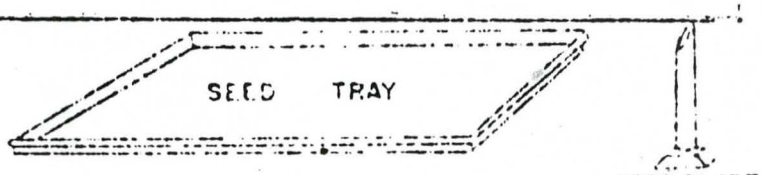
This rack is no longer used at the Eveleth Nursery.

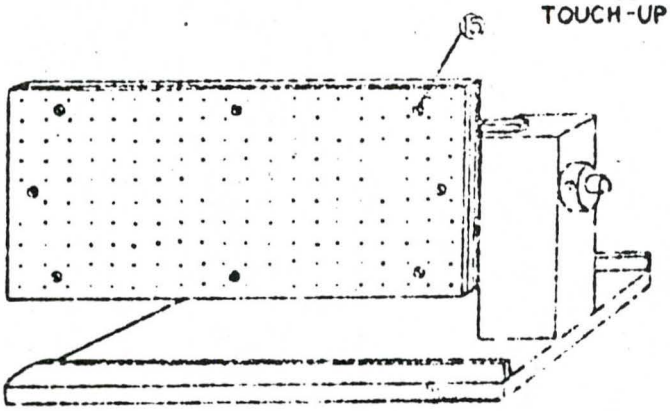
Tube Seeding Machine (Designed by Ontario Department of Lands and Forests)

TUBE SEEDING MACHINE



A





B

A SEEDER IN POSITION FOR SEEDING
B SEEDER IN POSITION FOR APPLYING SEED
C SEED HOPPER - *SEE PAGE 10*

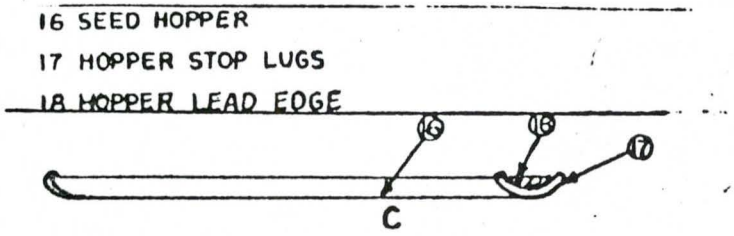
PARTS

1 SEEDER BASE
2 GUIDE RAILS FOR FLATS
3 SEED PLATE SUPPORT POST
4 SEED PLATE SWIVEL SHAFT
5 SWIVEL HUB AND KEY
6 SEED PLATE STOP LUG
7 VACUUM CHAMBER HOUSING
8 VACUUM PIPE
9 VACUUM HOSE CONNECTOR
10 VACUUM BLEEDER VALVE
11 BLEEDER VALVE GUIDE
12 BLEEDER VENT
13 SEED BASE PLATE
14 SEED PLATE
15 SEED PLATE ANCHOR SCREWS

Approximate Cost - $142.00

Manufactured by: Atlas Engineering & Machine Co., Ltd.
16 Eastern Avenue
Toronto, Ontario, Canada

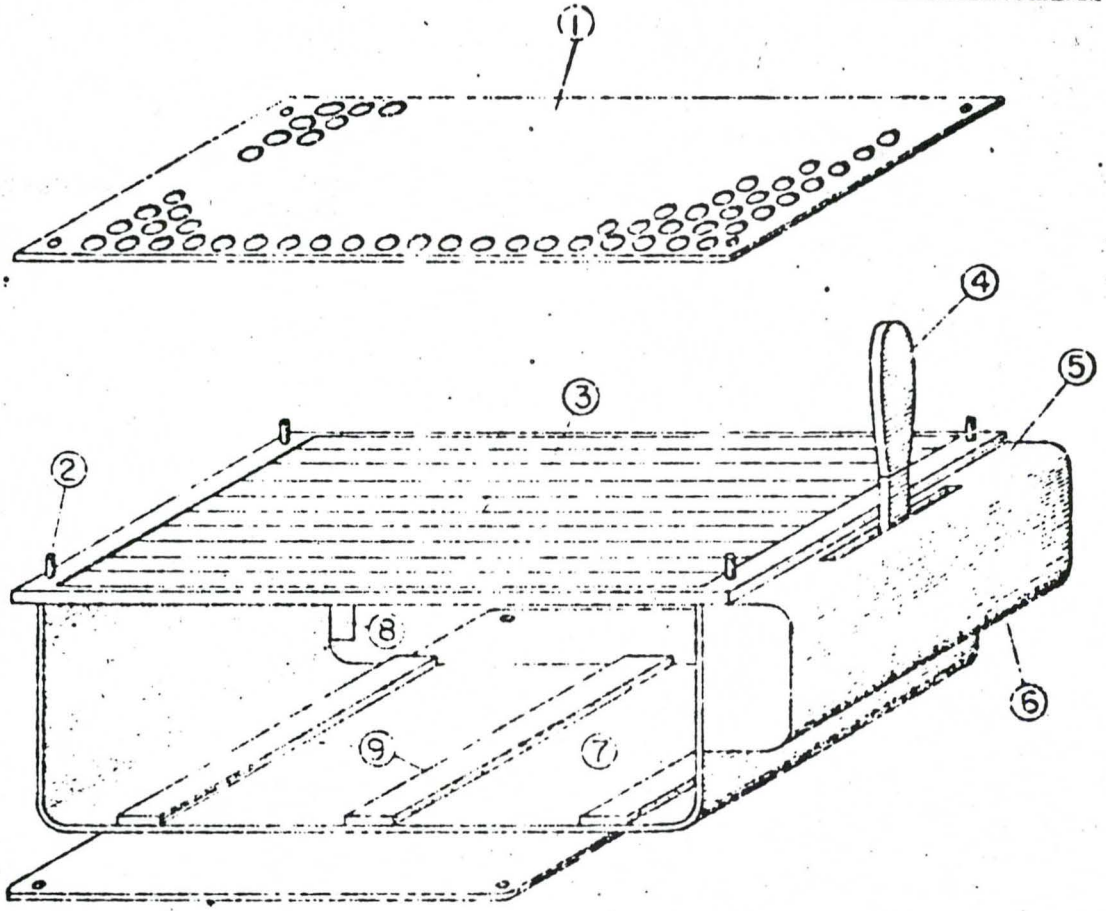
Seed Hopper - used with seeding machine



Approximate Cost - $2.50

Manufactured by: Redirack Industries, Ltd.
114 Clayson Road
Weston, Ontario, Canada

Tube Sanding Machine (Designed by Ontario Department of Lands and Forests)

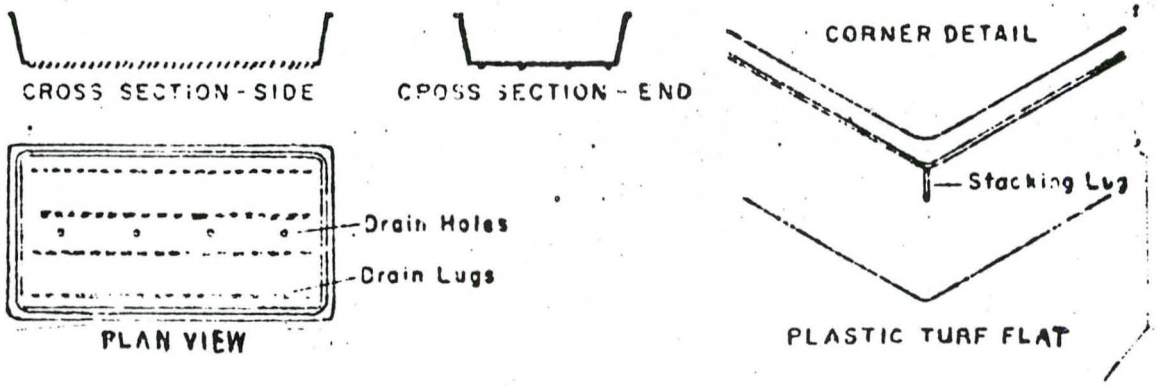


1 -SAND DEPTH PLATE
2-SAND DEPTH PLATE PEGS
3-SAND GATES
4-SAND DROP LEVER
5 -BEARING GUARD
6-BEARING HOUSING
7-GUIDE FOR FLATS
8-STOP FOR FLATS
9 -SLIDES FOR FLATS

Approximate Cost - $142.00

Manufactured by: Atlas Engineering & Machine Co., Ltd.
16 Eastern Avenue
Toronto, Ontario, Canada

Flats (Designed by Ontario Department of Lands and Forests)



Approximate Cost - $235.00/M

The flats hold 200 tubes, nested and made of high impact styrene.

Specifications: 6"x12-1/8" bottom, 2" deep, 7"x13-1/8" top, 7 degrees draft angle, 4 holes 1/8" diameter in bottom, and 4 ribs.

Manufactured by: Cooper Plastics Co., Ltd.
571 Adelaide Street E.
Toronto, Ontario, Canada

Plastic Tubes

Plastic tubes - 3" long x 0.5" diameter

Approximate Cost - $3.40/M

Split tube and made of 0.015-inch high impact styrene.

Manufactured by: Building Products of Canada, Ltd.
Mecro-Plastics Division
P.O. Box 300
Acton, Ontario, Canada

NURSERY PROCEDURES

Treatment of Seed

Seed to be used in the tubed seedling program must be given special treatment to give maximum and uniform germination in the shortest time. Stratification methods and time schedules vary by species. The methods used by nurserymen for spring-sown seed are usually satisfactory when there is sufficient time for cool treatment of moist seed. In an emergency it will be necessary to use short-term stratification methods. The nurserymen should prepare stratification procedures and schedules for the species used in their zone.

All seed in R-9 trials was treated with Captan to discourage damping-off. Fungicide-treated seed was then stratified as follows: Seed was held in tap water at 40° F. for 24 hours. The water was then poured off and the seed was placed in a dry plastic bag and placed in cold storage at 40° F. for 30 days. Seed stratified in this fashion began germinating in six days and germination was fairly complete at the end of two weeks.

The following seed treatment has been used and recommended by the Ontario Department of Lands and Forests.

Seed Treatment

Species	Treatment	
	Preferred	Emergency
White pine	A	C
Red pine	B	G
Jack pine	B	E
White spruce - large seed	A	I
small seed	A	H
Black spruce - large seed	B	D
small seed	B	F

A. SOAK SEEDS IN COLD (40° F.) TAP WATER FOR THREE DAYS. A convenient method would be to fill with water a plastic bag into which the seeds for treatment have been placed, and put the bag in a household refrigerator. DRAIN after three days and SURFACE DRY SEEDS with soft paper towelling to remove any free water. REPLACE seed IN A DRY PLASTIC BAG and tie the top to exclude excess air. KEEP AT 40° F. FOR 60 to 90 DAYS.

B. TREAT SEED AS IN (A) except KEEP AT 40° F. for only 30 DAYS before sowing.

C. TREAT SEED AS IN (A) except KEEP AT 40° F. FROM SEVEN TO 30 DAYS before sowing, depending on the time available. Seeds should be soaked at one time, placed in cold storage, then removed at required intervals after seven days.

D. SOAK SEEDS IN COLD (40° F.) TAP WATER FOR SEVEN DAYS.

E. SOAK SEEDS IN COLD (40° F.) TAP WATER FOR THREE DAYS.

F. SOAK SEEDS IN COLD (40° F.) TAP WATER FOR 17 HOURS.

G. SOAK SEEDS IN WARM (70° F.) TAP WATER FOR SIX HOURS.

H. SOAK SEEDS IN COLD (40° F.) 3% HYDROGEN PEROXIDE FOR 12 HOURS.

I. SOAK SEEDS IN WARM (70° F.) 3% HYDROGEN PEROXIDE FOR 12 HOURS.

Following a soak in water or hydrogen peroxide, the liquid is always drained and seeds spread on soft paper towelling and rubbed GENTLY with towelling until seeds are surface dried. The proper dryness is reached when the seed surface is no longer shiny. Care must be taken to avoid excessive drying (surface dried for more than one hour) or rough handling of moist seeds. Seeds should then be placed in a dry plastic bag, the bag tied at the top to exclude excess air and kept

at room temperature if seeds will be sown within three days, or placed in cold (40° F.) storage until required.

Loading Tubes with Soil

Type of soil. Soil used in the Region 9 trials was Mesabi Grow Peat with a PH of 4.5-5.0. The peat is fumigated with Dow MC-33 prior to use as a control for weeds and damping-off.

The peat is air dried following fumigation and then run through a ¼-inch screen. Since dry peat does not absorb moisture very readily the moisture content should be at the point where it is workable and still will not clog the loading equipment. The proper moisture content must be determined for the soil being used.

The following is the recommendation of the Ontario Department of Lands and Forests.

Preparation of Soil

The soil must be prepared by partial drying and screening through ¼-inch mesh. Dry the soil to a merely damp condition by spreading in the sunshine and raking the soil from time to time. Many organic soils are difficult to moisten if dried too completely. IT IS A REQUIREMENT THAT BEFORE THE MAIN SOIL LOADING OPERATION COMMENCES, A TEST BE MADE TO ENSURE THAT THE SOIL IN THE TUBES WILL SOAK UP WATER READILY. A suitable test is:

1. Load a box of tubes with soil, following procedure outlined on pages 16 and 17.
2. Spray the box with water from above, using a watering can or a hose with spray nozzle; allow about five minutes for the water to settle.

3. Open a number of tubes and examine the soil. If sufficient water has been added, the soil should be wet all the way through. If dry spots appear, and water is puddled on top of the soil or has run to the bottom, the soil is too dry for use.
4. If the soil is too dry, the supply for the day's use should be mixed with a damper, screened soil, to bring it to a more suitable moisture condition.
5. Repeat the test procedure until soil is suitable.

NOTE: IF THE SOIL BEING LOADED IS TOO WET, THE LOADING MACHINE WILL BECOME CLOGGED.

Quantity of Soil

The quantity of prepared soil required is one cubic foot per 10 flats of 200 tubes, i.e. 1/2 cubic foot per 1000 tubes.

Procedures for Loading Tubes 1/

1. To obtain the required height of space free from soil at the top of the tubes, adjust the tube clearing plate by means of the four set-screws on the bottom of the dowel table and then tighten the locking nuts. Load 2¼-2½ inches of soil into the tubes for all species (allow for settling to 2").
2. Adjust the feet on the loader sides so that when the sides are lowered with the soil-retaining frame the top rim of the frame is flush with the tubes and the feet resting on the table.
3. Lock the loader sides in the raised position and apply tubes to the dowels with the aid of the tube loading rack.

1/ Recommended by Ontario Department of Lands and Forests.

4. Fit the soil-retaining frame over the tubes so that the lifting rim rests on the loader sides.
5. Pour soil over the tubes until the soil-retaining frame is filled, then bump the loader on the table (or ground) to shake the soil down into the tubes and into the spaces between the tubes. Continue to add soil until all tubes are filled.
6. Unlock the loader sides and lower both the sides and the soil-retaining frame as far as the adjustable feet will allow.
7. Brush the excess soil from the tubes and then place an inverted flat over both the tubes and the soil-retaining frame.
8. With the fingers placed on the bottom of the flat and the thumbs in the semi-circular cut-out on the end of the loader, rotate the flat and loader until the flat is up-right and the loader upside down on top.
9. Lift one end of the flat (while the loader is still on top) about two inches and let it drop to shake the soil and tubes down firmly into the flat. Repeat with the other end.
10. With the thumbs placed on the thumb bars and fingers on the side handles lift the sides until they stop at the off-set feet. Holding the thumb bars firmly down continue to lift on the side handles but in a seesaw motion until the dowels are free from the tubes and then lift the loader away.
11. Pour additional soil between the sides of the flat and the soil-retaining frame and bump lightly to shake the soil down. Carefully remove the soil-retaining frame and the loading operation is complete.

Tube Loading Machine - Description and Maintenance

1. Operational Cleaning

(a) To maintain a high degree of efficiency from the loading machine, all excess soil must be brushed from around the dowels and off the top of the clearing plate after each loading.

(b) After loading every third or fourth flat, the sides of the loader should be dropped to the off-set feet, the clearing plate raised by pressing on the thumb bars, and the loader bumped lightly on its sides to remove soil from under the clearing plate. A stiff wire run under the plate and between the dowels will dislodge compacted soil.

2. Periodic Cleaning

The tube loader should be taken apart from time to time for a thorough cleaning under the following procedures:

The dowel table is one unit and must not be dismantled. The loader sides are removed from the dowel table by undoing the side-stop lugs and lifting the sides off. The tube clearing plate is removed by undoing the anchor nuts on the thumb bars and lifting the thumb bars from the push rods. Remove the locking nuts and springs, and then lift the clearing plate from the dowel table. Do not remove the push rods from the clearing plate.

To re-assemble the loading machine, place the tube clearing plate on a flat surface with the push rods up. Invert the dowel table and fit it over the clearing plate so that the push rods go through the appropriate holes in the dowel table with the dowels fitted into the

holes on the clearing plate and resting on the flat surface. Place the springs on the push rods, then screw on the locking nuts to a depth equal to the thickness of the thumb bars plus the thickness of the anchor nut. Fit the thumb bars onto the push rods and compress the springs so that the bars rest on the locking nuts and secure with the anchor nuts. Replace the loader sides and fasten stop lugs in place.

3. Adjustments

The re-assembly of the tube loading machine will set the tube clearing plate at its proper adjustment for clearing the tubes from the loader.

The four set-screws on the underside of the dowel table will adjust the clearing plate for the required space to be left free from soil at the top of the tubes. To make this adjustment simply loosen the locking nuts on the screws and adjust to hold the clearing plate at the desired height and then secure the locking nuts.

To set the side-drop guides on the tube loading machine, fill the loader with tubes and place the soil-retaining frame over them so that it rests on the loader sides. Loosen the side-drop guides so that they move freely and lower the sides of the loader until the top rim of the soil-retaining frame is flush with the tops of the tubes. Tighten the side-drop guides at this level to hold and the adjustment is completed.

Efficiency in the tube loading procedure can be improved by procuring tubes packed in segmented boxes. Tubes received in this fashion

can be placed directly on the loading machine by hand, eliminating the extra step of placing tubes on loading racks prior to putting them on the loading machine. All future orders for tubes should specify shipment in segmented boxes to assure this labor-saving feature.

Seeding Tubes

1. Locate the seeding equipment away from the loading and sanding operations to avoid dust or grit blocking the holes in the seed plate.

2. Start the seeding prior to sanding and initial watering.

3. Prior to starting, blow out the seed plate by attaching the hose to the air outlet on the vacuum and with the bleeder valve closed on the seeder, turn on the vacuum for about a minute.

4. Turn off the vacuum and change the hose over to the air intake on the vacuum. Rotate the seed plate to a position just past the 90° angle. Place the seed tray under the plate.

5. Pour a sufficient quantity of seed into the seed hopper so that they spread evenly over the entire length of the hopper. Do not attempt to fill the hopper. Pour a quantity of seed into the seed plate touch-up tube and place it to one side. The seed plate touch-up tube can be made easily from a plastic stamp-wetting tube by removing the sponge on the end and cutting the opposite end to form a lip as shown in the illustration of accessories for the "Tube Seeding Machine". Touch-up tubes can be made also from one of the plastic tubes by simply closing the split with tape, sealing one end with a cork and cutting the opposite end to form a lip.

6. Adjust the bleeder valve on the seeder to the recommended position to suit the size of the seed being used, as shown below:

   a. Bleeder valve closed - white and red pine.

   b. Bleeder valve open halfway - jack pine.

   c. Bleeder valve open three quarters - white spruce.

   d. Bleeder valve open all the way - black spruce.

   Turn the vacuum on and then place the lead edge of the seed hopper against the seed plate just above the top row of holes and with the lugs on the ends of the hopper spanning the plate.

7. Tip the hopper sufficiently to cause the seeds to slide against the seed plate without causing them to heap. With a side-to-side motion and bumping the lugs against the plate sides start moving the hopper horizontally down, keeping the lead edge against the plate face. The side-to-side motion should maintain an even flow of seeds against the plate. Continue to move the hopper down until it clears the bottom of the plate.

8. Using the seed plate touch-up tube check the rows of seeds held to the seed plate, starting from the top right hand corner and checking down each row to the left hand side. Where seeds are missed on the seed plate a slight bump with the touch-up tube close to the hole will add a seed. Where seeds are bunched on a hole merely remove them and add a seed.

9. Rotate the seed plate to a horizontal position with the plate facing downward. Close bleeder valve; it helps prevent loose seed falling off. Remove the seed tray and then slide a prepared flat of tubes

under the plate as far as it will go. Adjust to line the tubes under the edges of the plate.

10. Unplug the hose from the vacuum while the vacuum is still running, and the seeds will drop directly into the tubes. When spruce seed is being used it is necessary to tap the top of the seed plate lightly to assure that all seeds have dropped.

Tube Seeding Machine - Description and Maintenance

1. Operational Cleaning

(a) Isolate the seeding equipment from the loading and sanding operations and keep the seeding area clean at all times.

(b) Before seeding each flat attach the hose to the air outlet on the vacuum machine, close the bleeder valve, and blow out the holes in the seed plate.

(c) Keep the seeder base, seed tray and seed hopper clean at all times to prevent loose dust or grit from being picked up on the seed plate by the suction.

2. Periodic Cleaning

Use only a fine steel wire to clear any blocked holes in the seed plate that are not cleared by blowing. Do not use pins, needles, nails, etc. as they will enlarge the holes in the seed plate and cause bunching of seeds on the holes.

If blockages cannot be cleared with the wire from the front of the plate, then remove the plate and clear it from the back.

3. Vacuum Machine

To prevent overheating of the vacuum machine, leave it running while the hose is disconnected from it. Do not leave the machine running for long periods while it is connected to the seeder.

Sanding

Sand cover over the seeds is required to encourage penetration of the soil by the roots of germinating seeds, and to serve as a mulch after germination is complete. EXCESSIVE SAND COVER WILL REDUCE GERMINATION; hence, the following recommendations for sand cover are given by species:

Species	Depth of sand cover on seed
Black spruce	1/16 inch
White spruce	1/8 inch
Jack pine	1/8 inch
Red pine	1/4 inch
White pine	3/8 inch

THE SAND SHOULD BE MEDIUM TO COARSE in texture after screening out gravel sizes using fly screen. A sample of a suitable sand will be supplied for comparison.

Fine sands tend to pack too tightly, thus inhibiting normal seedling development.

THE SAND SHOULD HAVE A PH of 6.0 or LOWER, to discourage damping-off.

Sand Application

1. Operate the sand release lever to open and close the gates on the sand applicator a few times to make sure that it is free from grit.

2. Select the desired sand depth plate to suit the species of the seed to be covered with sand (see above).

3. Fit the sand depth plate on the sand applicator making certain that it is firmly seated into place.

4. Slide a flat of seeded tubes into the sand applicator as far as it will go.

5. Pour sand over the sand depth plate and brush it around until all the holes in the plate are filled. Then brush off the excess sand.

6. Pull the lever to open the gates and drop the sand into the tubes. If damp sand is being used it may be necessary to pull the lever several times to release the sand from the holes. Remove the flat and the sand application procedure is complete.

R-9 experience showed that the seeding operation must include a solid covering of the seed prior to germination. Flats which were allowed to germinate without covering did not grow well. Initial germination was successful but after a few days the stem curled and many seedlings died. Conversely, the seeds which received ¼ inch of soil covering continued to grow well after germination with only minor mortality.

We deviated from the suggestions made by the Canadians concerning the seed covering operation. They are using sand as a covering medium and we found that dry peat--the same medium as used for tube loading--worked very well. It appears that dry peat works equally as well as sand for covering and eliminates the need of handling two soil sources. The peat

must be dry for successful covering, however. The peat should be screened so that only fine-textured material is used for covering.

Watering

The initial watering of the soil in the tubes follows directly after the seeding and sanding.

On the bottom of the flats are four ribs and four 3/16 in. holes along the centre line between the ribs. This allows the flats to be placed in a tank containing a depth of one inch of water so that the soil in the tubes can take up water to saturation by seepage through the holes. The ribs permit free access of the water under the flats and the holes are not blocked by contact with the bottom of the tank.

Once the soil in the tubes has reached saturation, the flats are lifted from the tank and placed on a sheet of plastic.

Placing Flats in Greenhouse

On the completion of the watering operations, the flats are moved directly to the greenhouse or placed in cold storage.

Each counter in the greenhouse should be designed so that the flats will fit between the angle runners with the rims or bottom resting on the edge of the runners.

While placing the flats in the greenhouse, make sure that each unit of production is kept together so that they can be covered with wet burlap for germination as a single unit. The burlap should hang over the edge of the flats.

Greenhouse Culture of Seedlings

Approximate Growing Schedule - Days

Species	Germinate	Grow	Harden-off	Age at Planting
Red pine	8	12	10	30
Jack pine	8	12	10	30
White pine	18	7	10	35
Black spruce	8	32	10	50
White spruce	12	28	10	50

Germination of Seeds

To maintain uniformly high moisture conditions for seed germination, the flats should be covered with burlap. Keep burlap moist. Do not saturate. During hot, sunny weather, it is possible for temperatures to rise, under the burlap, to dangerous levels. DO NOT ALLOW TEMPERATURES TO RISE ABOVE 100° F. IN THE TUBES. This temperature should be checked at short intervals on sunny days by inserting a thermometer through the burlap, allowing it to rest on the soil surface. Remove the burlap whenever necessary and replace it as soon as sun conditions are no longer dangerous.

The burlap should be removed finally when approximately 50% of the seeds have germinated, or if germination is irregular, as soon as the tallest seedlings begin to touch the burlap.

Watering

After the burlap is removed, the seedlings may require their first watering. This may be done using the fog nozzle or with a watering can having a fine spray head.

The requirements for watering must be determined for each greenhouse by examining the soil in some tubes in each section of each greenhouse. Tubelings must be watched every day until they leave the nursery to protect against insects, birds, mice and assure proper moisture.

Experience gained in this way will provide the best understanding of a too wet or too dry condition for the various species and ages of stock.

As general guides, it may be said that:

1. Under-watering leads to faster main root growth, with the chance that roots would become intertwined on the bottom of the flat.
2. Over-watering of older seedlings (four weeks or older) can cause root rotting. Over-watering of young seedlings (up to two weeks) can lead to damping-off.

Each watering must be sufficient to completely moisten the soil to the bottom of the tube, but complete saturation for more than a few days is to be avoided.

A final watering at the planting site is desirable, provided that the saturation is not so severe as to cause the soil to run out of the tubes when they are lifted.

Insect and Disease Control

Be prepared to protect against damping-off. Usually Captan is applied with the first watering. If protection is necessary, apply 50% Captan (two tablespoons wettable powder per gallon of water) as a spray once weekly.

Temperature

Try to maintain a relatively constant temperature for germination as follows:

Species	Recommended Germinating Temperatures
Red pine	85° F.
Jack pine and Black spruce	80° F.
White spruce	80° F.
White pine	75° F.

Although temperatures as low as 70° F. or as high as 90° F. may not be critical, they would result in delayed or irregular germination.

After the burlap is removed from the flats, hold the prescribed germinating temperatures as well as possible until about 80% of the seedlings appear (five to 15 days), then reduce the temperatures to the following levels.

GROW WHITE PINE, JACK PINE AND WHITE SPRUCE with 70° F. in the DAYTIME (16 hrs.) AND 50° F. AT NIGHT.

GROW RED PINE AND BLACK SPRUCE with 75° F. in the DAYTIME (16 hrs.) and 50° F. at NIGHT.

Fans will aid in the distribution of heat within the greenhouse. In summertime, it may be necessary to open greenhouse sides or ends to maintain safe temperatures. During the growing period, temperatures over 80° F. for an extended period are undesirable. Nighttime temperatures below 40° F. should be avoided, otherwise the prescribed daytime temperatures may be difficult to obtain and growth will be retarded.

Hardening-Off of Seedlings

PLANTS SHOULD NOT BE MOVED DIRECTLY FROM A WARM GREENHOUSE TO THE FIELD PLANTING SITE. It is likely that the conditions prevailing during growth in the greenhouse will not have encouraged the development of hardy stock. For purposes of our work, HARDENED-OFF STOCK IS STOCK WHICH HAS DEVELOPED SOME RESISTANCE TO INJURY by heat, drought, damping-off, fungi and frost; although it should be realized that there are many stages of the hardened-off condition (see Appendix for a guide to judging seedling hardiness).

PLANTING OF SEEDLINGS IN THE SUCCULENT CONDITION SHOULD BE DONE ONLY WHEN NO FROST IS ANTICIPATED.

TO ENCOURAGE THE DEVELOPMENT OF HARDY SEEDLINGS, the following conditions are required: (a) FOR AT LEAST ONE WEEK PRIOR TO PLANTING, OUTSIDE TEMPERATURES SHOULD PREVAIL. Therefore, greenhouses should be well ventilated even at night unless frost protection is required. (b) AVOID FERTILIZING AND OVER-WATERING during the final week of hardening-off.

If seedlings are moved outside the greenhouse for the hardening-off period, PROTECTION MUST BE AFFORDED against mice, frost, hail or other dangers. This is the practice when a single greenhouse is used.

The ease with which seedlings may be hardened-off, and the damage which may occur despite having hardy stock, will vary with the location and time of year. Stock will be most vulnerable in the early spring and late fall, but not necessarily safe from damage due to extreme conditions at any time.

Greenhouse culture will be necessary to produce tubelings for early summer planting but stock which is not scheduled for planting before mid-July can be produced successfully outside.

In order to compare results in germination and development of greenhouse-cultured tubelings and those started outside, 2000 tubelings were placed under 50% shade immediately after seeding. Germination occurred one day earlier than greenhouse-cultured tubelings and generally appeared to have better color and vigor. Where space and shade is available the practice of growing tubes outside appears desirable and should be considered for future tubeling production. This will necessarily be only a supplement to greenhouse growing if stock is to be available for planting throughout the frost-free season.

Summary

All techniques used were the same as those used by the Ontario Department of Lands and Forests with the few exceptions noted above (use of dry peat, peat for covering seed rather than sand, and growing tubelings outside the greenhouse under shade). Our production can easily reach 8000 to 10,000 per man-day and it appears that red pine can be produced for planting within four weeks. Cost of production will likely be around $10 per thousand. Early observations indicate planting production by force account at 1000 per man-day where travel time is not great. Contract planting on the Superior National Forest was $20 to $22 per thousand tubelings.

FIELD PLANTING

Site. The site requirements for tubed seedlings are not changed from those for direct seeding or seedling planting of a specific species.

Site preparation is essential for tubed seedlings and is a bit more critical than required for nursery seedling stock. Site preparation is required to remove the following.

1. Shrub or overstory competition.
2. Deep, dry duff.
3. Heavy grass competition.

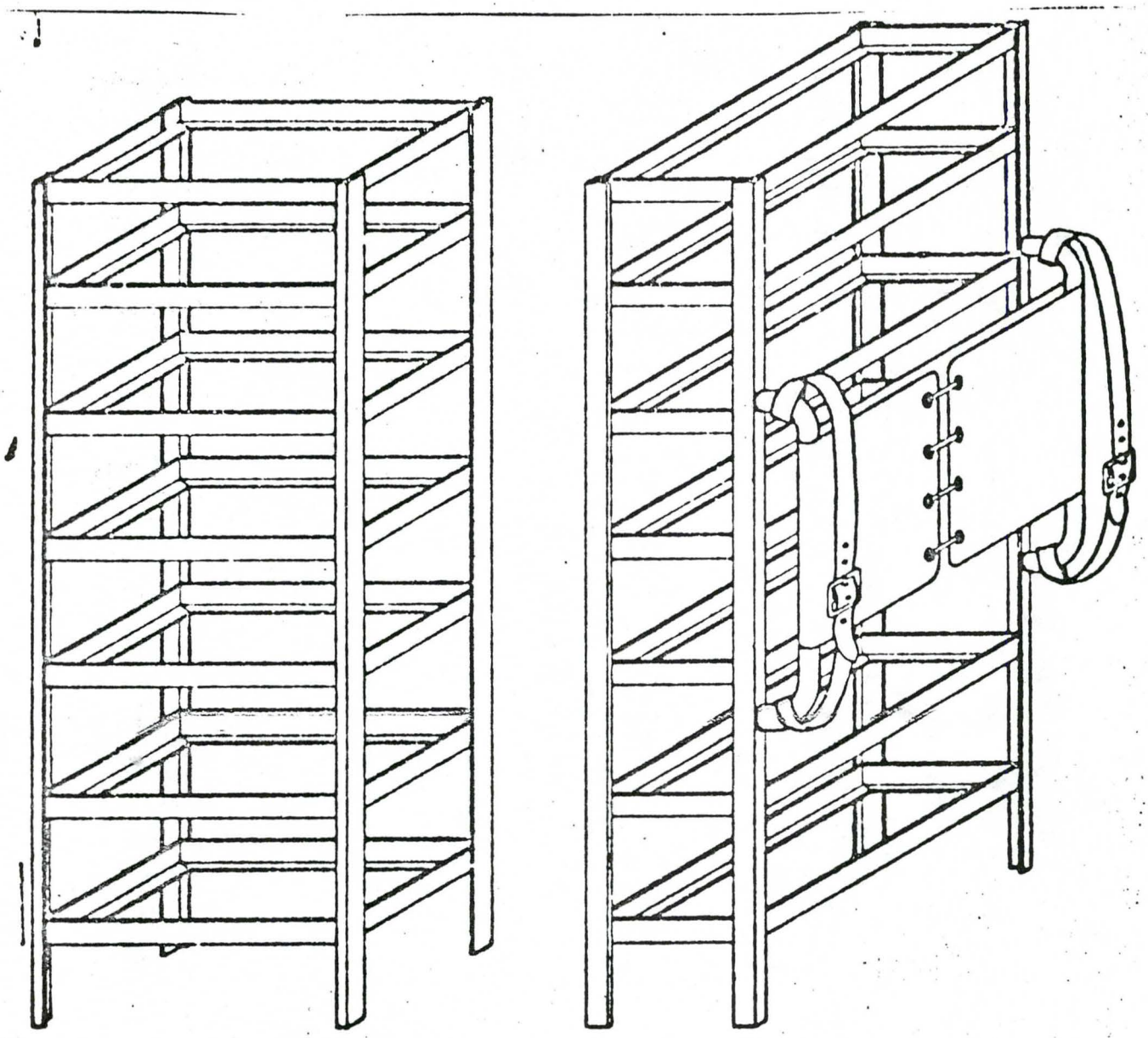
There is no change from standard Regional site preparation practices. The planting hoe is used to clear the spot where the tubed seedling is to be planted.

Transporting tubed seedlings. Without proper storage facilities there should be no more than two days' supply of tubed seedlings at the planting site. This requirement places transportation of the seedlings as a major issue. The following items must be fully considered when shipping seedlings.

1. Do not water just prior to shipment. The wet soil tends to pack when subject to vibration.
2. Protect from wind, ship in covered van or truck.
3. Avoid rough roads.
4. Do not stack flats unless tiered racks are used.

The back-pack racks should be used for transporting the tubed seedlings on the job. The racks in use are those designed by the Ontario Department of Lands and Forests and have a capacity of six flats. Reference, sketch on page 32.

Tubed Seedling Transporting Rack



Planting. The planting tool is a standard garden hoe to which has been attached an adjustable dibble. (See page 35). The handle may be shortened to about three feet.

The hoe is used to remove litter and dry duff and prepare the planting spot. The following requirements should be met:

1. Shrub and other low overstory competition must be removed.
2. Remove deep, dry duff.
3. Remove grass.

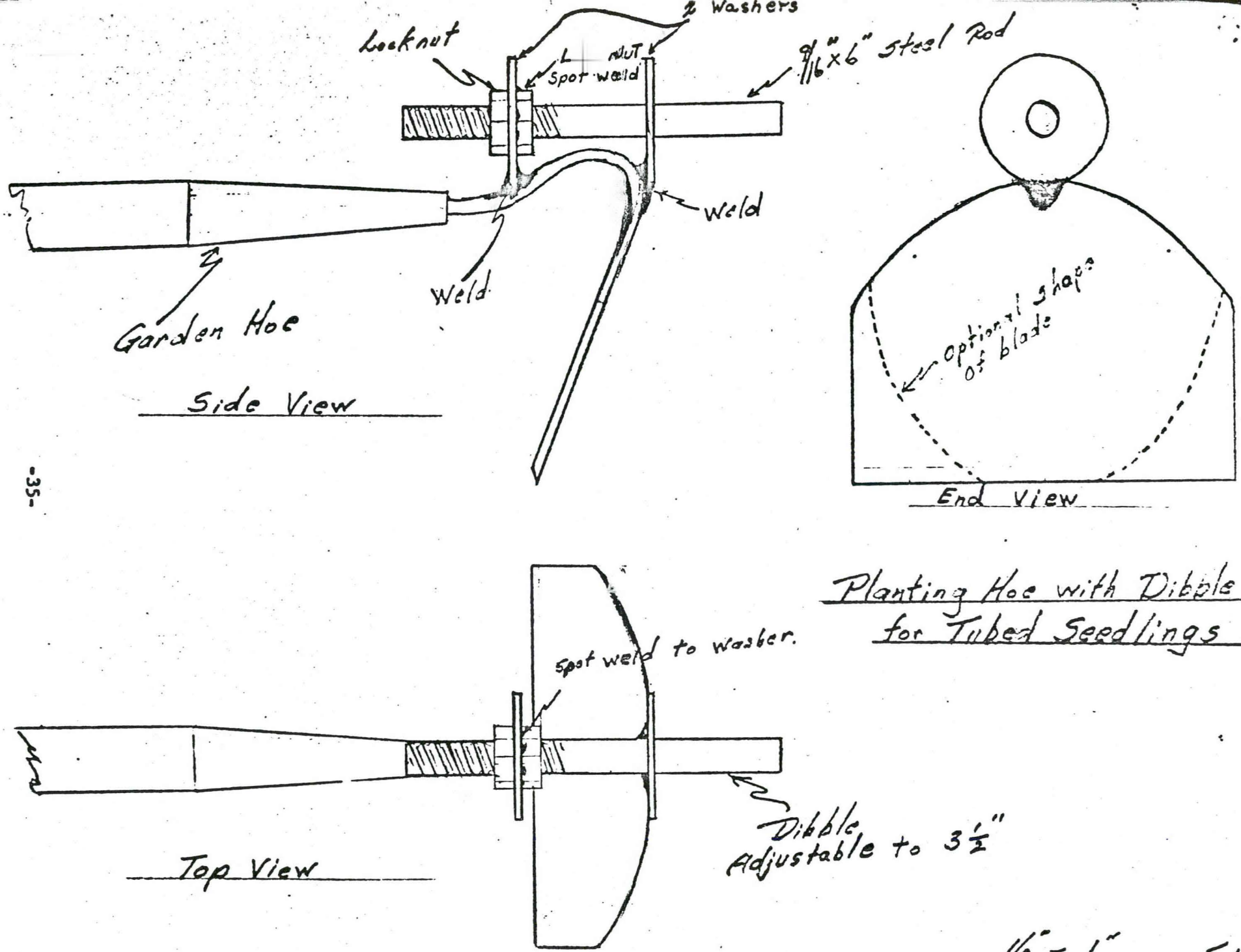
The dibble is used to prepare the hole for the tubed seedlings. The depth of the hole must be varied with soil conditions. The minimum depth for loose soil is 2½ inches. The depth for firm soil is 3 inches or the full length of the tube. The hole should be perpendicular, not slanting. After inserting the tube the soil is firmed with the fingers so as to exclude air and help retain moisture. The essential requirements for placing tubes are as follows:

1. Avoid depressions to prevent flooding.
2. Avoid dry, rotten logs.
3. Avoid exposed soil when possible.
4. Plant in shade of stump, rock, log, etc.
5. Plant on fringe of scalped spot.
6. Set tube tight in the soil.

The planting box is designed to hold two flats (400 tubes) of seedlings. If desired the same design can be used for a single flat by reducing the sides to two inches (see pages 36 and 37).

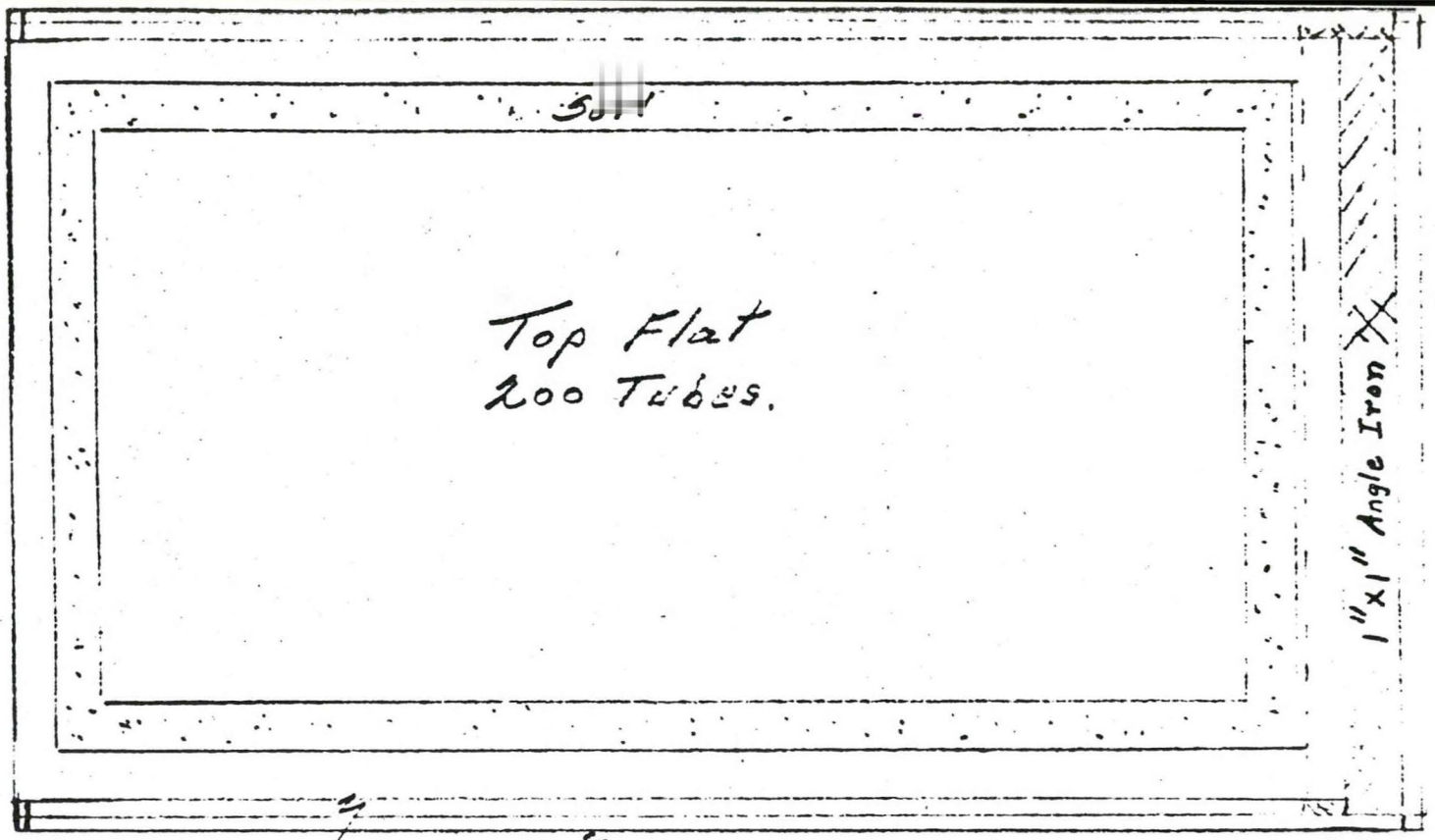
Spacing. Until more data are available on survival it is recommended that about 25 percent more tubed seedlings be planted per acre than is normal for nursery stock of the same species.

Planting season. The tubed seedlings may be planted any time when the soil is not frozen from early spring until late fall. It is recommended that fall planting be terminated about two or three weeks prior to heavy fall frosts to allow the tubes to settle before the ground is frozen. This is advisable to prevent excessive frost heaving. Planting after August 15 in Minnesota is very questionable.

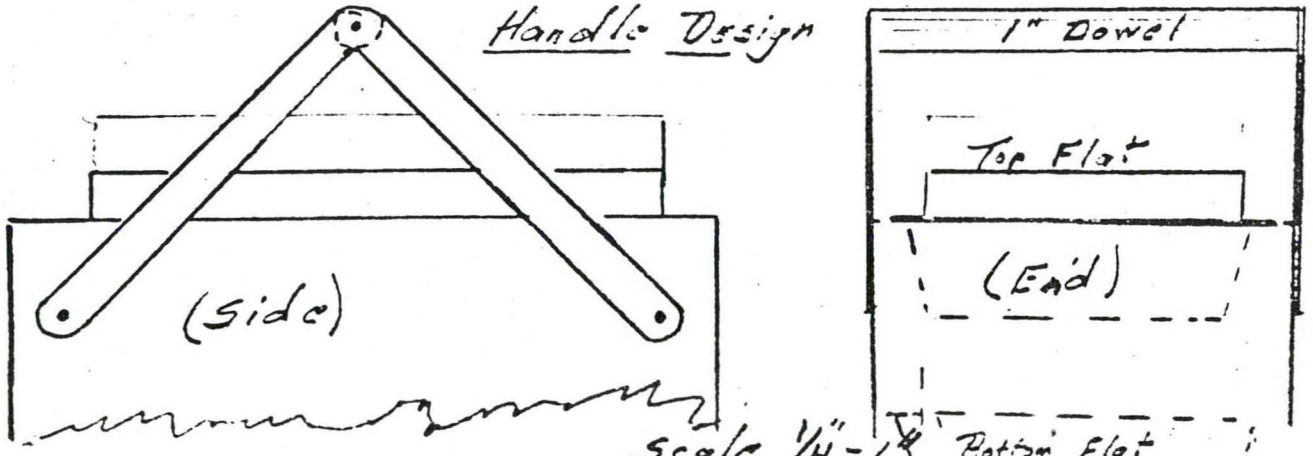


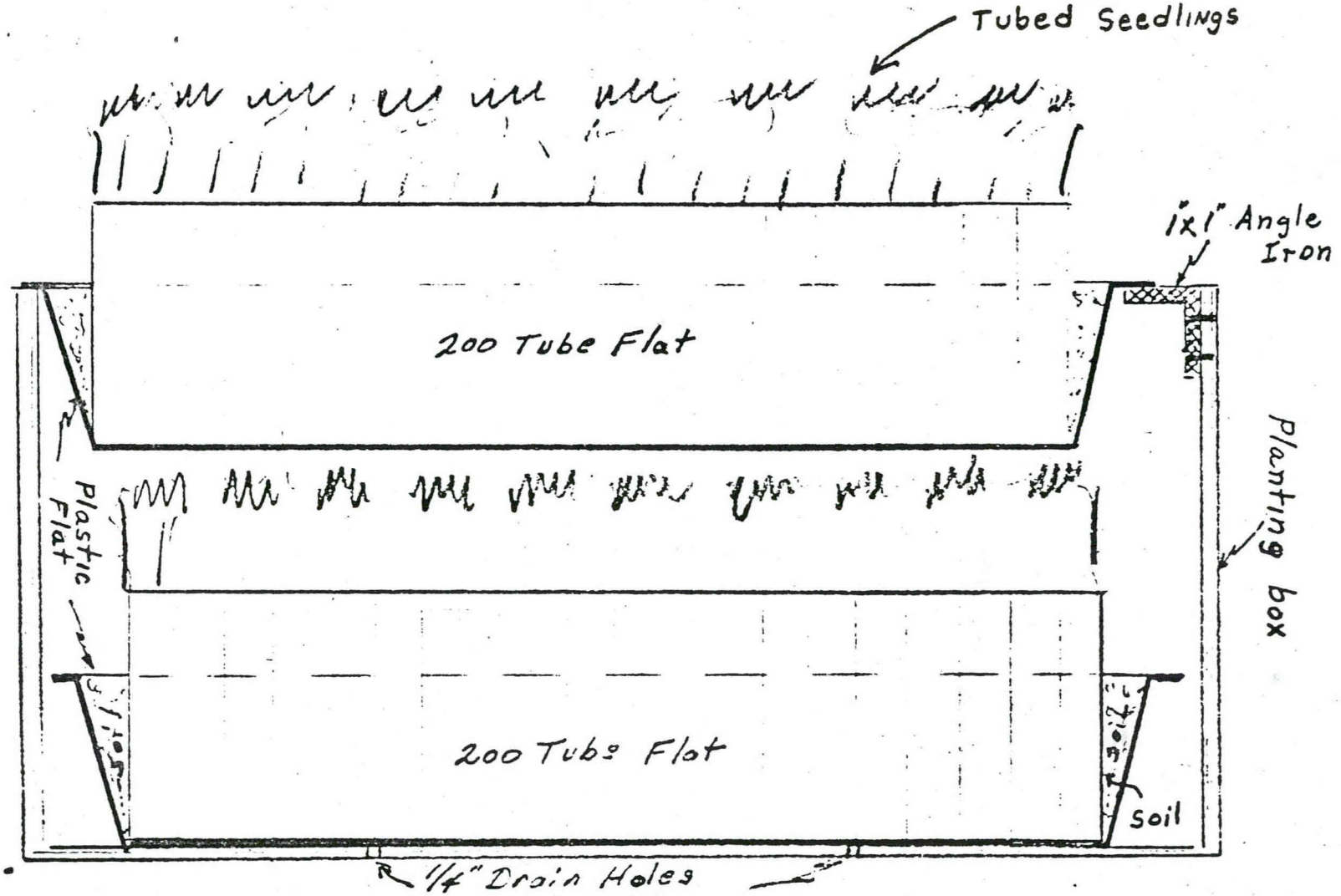
Planting Hoe with Dibble for Tubed Seedlings

½" = 1" E.N.L.



Planting Box for Two Flats (400 tubes)





(Side)

Planting Box for Two Flats (400 Tubes)

Scale 1/2" = 1"

APPENDIX

1. Ontario Greenhouse Specifications.
2. Ontario Theoretical Production Schedules.
3. Ontario Guides to Seedling Stages of Development.
4. Abstract - Experimental Planting of Tubed Seedlings.
   1958. M. M. McLean.
5. Abstract - Preparation and Planting of Tubed Seedlings.
   V. H. H. Williamson.

APPENDIX

Greenhouse Specifications
(Ontario Department of Lands & Forests)

1. Overall dimensions 16 ft 0 in. x 12 ft 6 in. x 8 ft 4 in. high.

Capacity:	2 outer shelves 54 flats each	= 108
	1 centre shelf 108 flats	= 108
	Total No. flats	216
	Total No. tubes	43,200

2 aisles each 2 ft 0 in. wide.

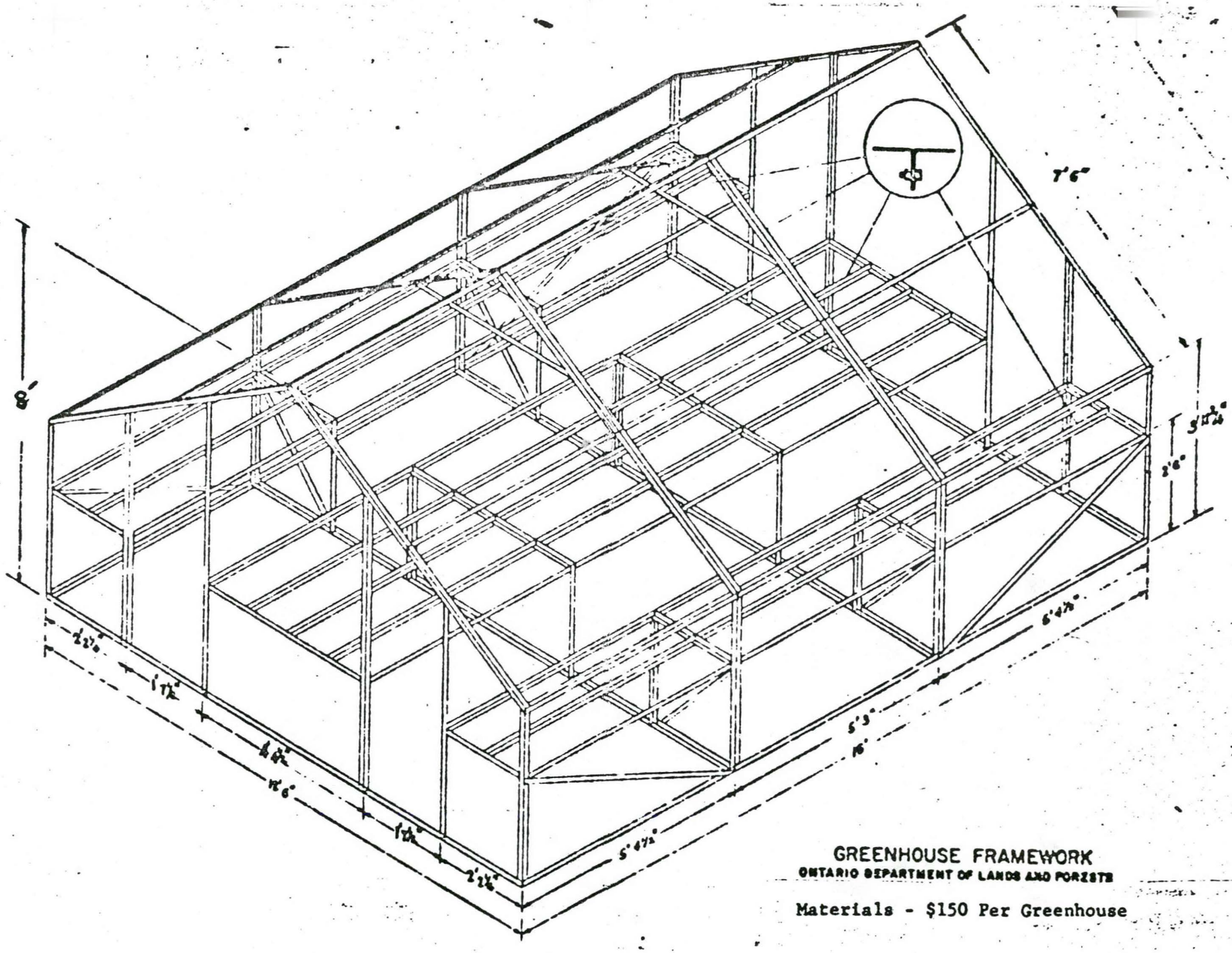
Plastic Sheeting
1 roll 6 ft x 250 ft x 4 mil will cover sides and end walls for four greenhouses.
1 roll 10 ft x 200 ft x 4 mil will cover the roof areas for five greenhouses.

Wooden Lath (rough-cut)
440 ft x 1½ in. wide x ½ in. thick for one greenhouse 70 ft x 3 in. wide x ½ in. thick for one greenhouse
1 gross screw-eyes for one greenhouse
Sills recommended under each greenhouse

2. Greenhouse Equipment
1 space heater (50,000 B.T.U.) for two greenhouses
1 electric fan for each greenhouse
9 electric lights for each greenhouse (if required)
Electric power - hydro (if available) or generator
1 maximum-minimum thermometer for two greenhouses
Water supply
Oil tanks

3. Greenhouse Installation
Greenhouses are erected in pairs end to end, 2 feet apart and in a north-south direction. The plastic cover is left off the adjacent ends, but the span between the two greenhouses is covered with plastic. A space heater is installed between the two greenhouses to service both.

4. There has been difficulty with heat control. It is advisable to get commercial greenhouse (Fibreglass) with controls. Locate at District H.Q. Complete cost - $10,000 for 24' x 60'.



GREENHOUSE FRAMEWORK

ONTARIO DEPARTMENT OF LANDS AND FORESTS

Materials - $150 Per Greenhouse

THEORETICAL SPRUCE PRODUCTION BASED ON 7 WEEKS IN GREENHOUSE

No. Greenhouses	GREENHOUSE CAPACITY BY 7-WEEK PERIODS		
	7 Weeks	14 Weeks	21 Weeks
2	86,000	172,000	250,000
4	172,000	344,000	516,000
6	258,000	516,000	774,000
8	344,000	688,000	1,032,000
10	430,000	860,000	1,290,000
12	516,000	1,032,000	1,548,000
14	602,000	1,204,000	1,806,000
16	688,000	1,376,000	2,064,000
18	774,000	1,548,000	2,322,000
20	860,000	1,720,000	2,580,000
22	946,000	1,892,000	2,838,000
24	1,032,000	2,064,000	3,096,000
IF PLANTING STARTS JUNE 1.			
Start to Seed	13 April	1 June	20 July
Start to Plant	1 June	20 July	7 Sept.
Finish Planting by	5 July	23 Aug.	12 Oct.
IF PLANTING STARTS JUNE 15.			
Start to Seed	27 April	15 June	3 Aug.
Start to Plant	15 June	3 Aug.	21 Sept.
Finish Planting by	20 July	6 Sept.	25 Oct.

Based on production and planting of 43,000 per day.

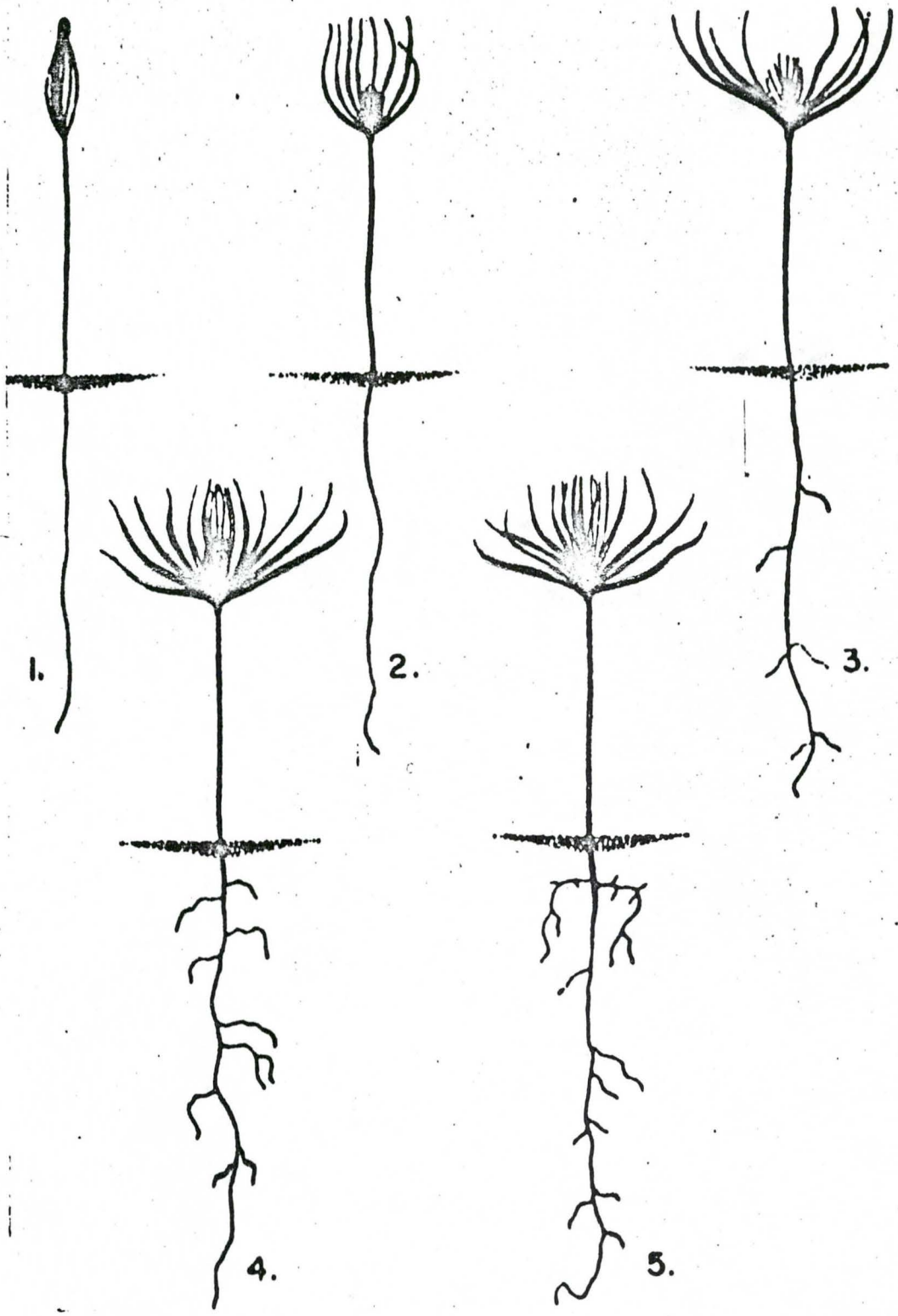
THEORETICAL PINE PRODUCTION BASED ON 4 WEEKS IN GREENHOUSE

No. Greenhouses	GREENHOUSE CAPACITY BY 4-WEEK PERIODS				
	4 Weeks	8 Weeks	12 Weeks	16 Weeks	20 Weeks
2	86,000	172,000	258,000	344,000	430,000
4	172,000	344,000	516,000	688,000	860,000
6	258,000	516,000	774,000	1,032,000	1,290,000
8	344,000	688,000	1,032,000	1,376,000	1,720,000
10	430,000	860,000	1,290,000	1,720,000	2,150,000
12	516,000	1,032,000	1,548,000	2,064,000	2,580,000
14	602,000	1,204,000	1,806,000	2,408,000	3,010,000
16	688,000	1,376,000	2,064,000	2,752,000	3,440,000
18	774,000	1,548,000	2,322,000	3,096,000	3,870,000
20	860,000	1,720,000	2,580,000	3,440,000	4,300,000
22	946,000	1,892,000	2,838,000	3,784,000	4,730,000
24	1,032,000	2,064,000	3,096,000	4,128,000	5,160,000
IF PLANTING STARTS JUNE 1.					
Start to Seed	4 May	1 June	29 June	27 July	24 Aug.
Start to Plant	1 June	29 June	27 July	24 Aug.	21 Sept.
Finish Planting by	5 July	2 Aug.	29 Aug.	26 Sept.	25 Oc .
IF PLANTING STARTS JUNE 15.					
Start to Seed	18 May	15 June	13 July	10 Aug.	-
Start to Plant	15 June	13 July	10 Aug.	7 Sept.	-
Finish Planting by	19 July	15 Aug.	13 Sept.	11 Oct.	-

Based on production and planting of 43,000 per day.

WHITE PINE

Stages of Development
(Grown in Greenhouse)

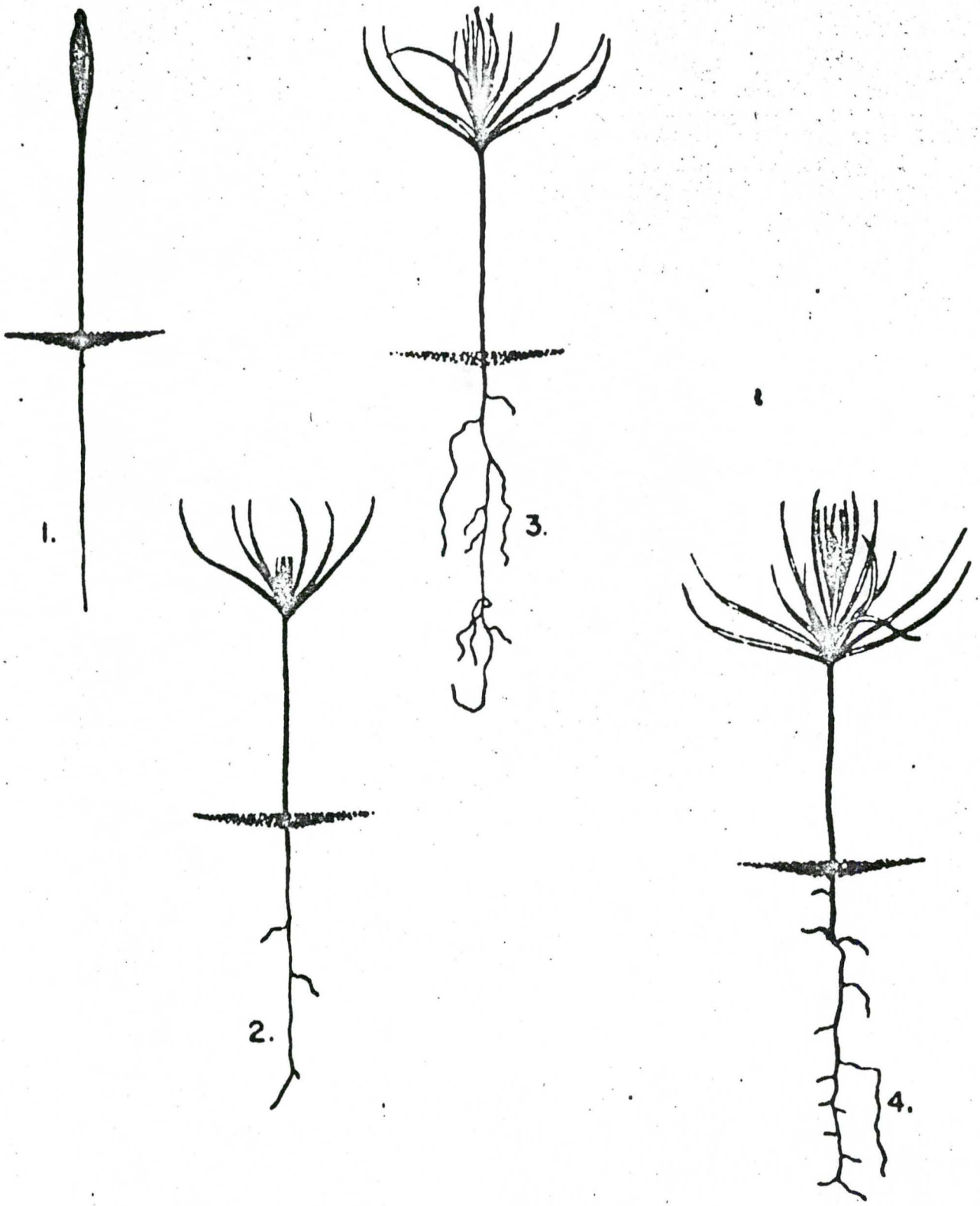


WHITE PINE

Stage of Development	Hardiness Characteristics
1. Seed coats adhering to cotyledons. Primary needles just visible. Stem green, greenish brown to reddish brown. (Age up to 2 weeks.)	Seedlings subject to damping-off damage. Tissues very succulent, subject to drought, heat, frost and chill damage.
2. Seed coat thrown off. Primary needles up to ½ in. long. Stem green and reddish brown to light chocolate brown. (Age 1 to 3 weeks.)	Only slightly more hardy than in (1) above.
3. Stem dark chocolate brown, partly reddish. Primary needles usually well developed (½ in. or longer). Branch roots developing. (Age 2 to 4 weeks.)	Essentially safe from damping off. Only moderate resistant to drought, heat, frost and chill injury.
4. Stem chocolate brown to red. Secondary needles developing. (Age 3 to 5 weeks.)	Considerable resistance to drought, heat and cold.
5. Stem light brown, appearing wrinkled under hand lens. Secondary top growth may occur; if so continues until bud set. (Age 4 to 6 weeks.)	Seedling well hardened, subject only to extremes of drought, heat and cold, except for succulent secondary growth.

RED PINE

Stages of Development
(Grown in Greenhouse)

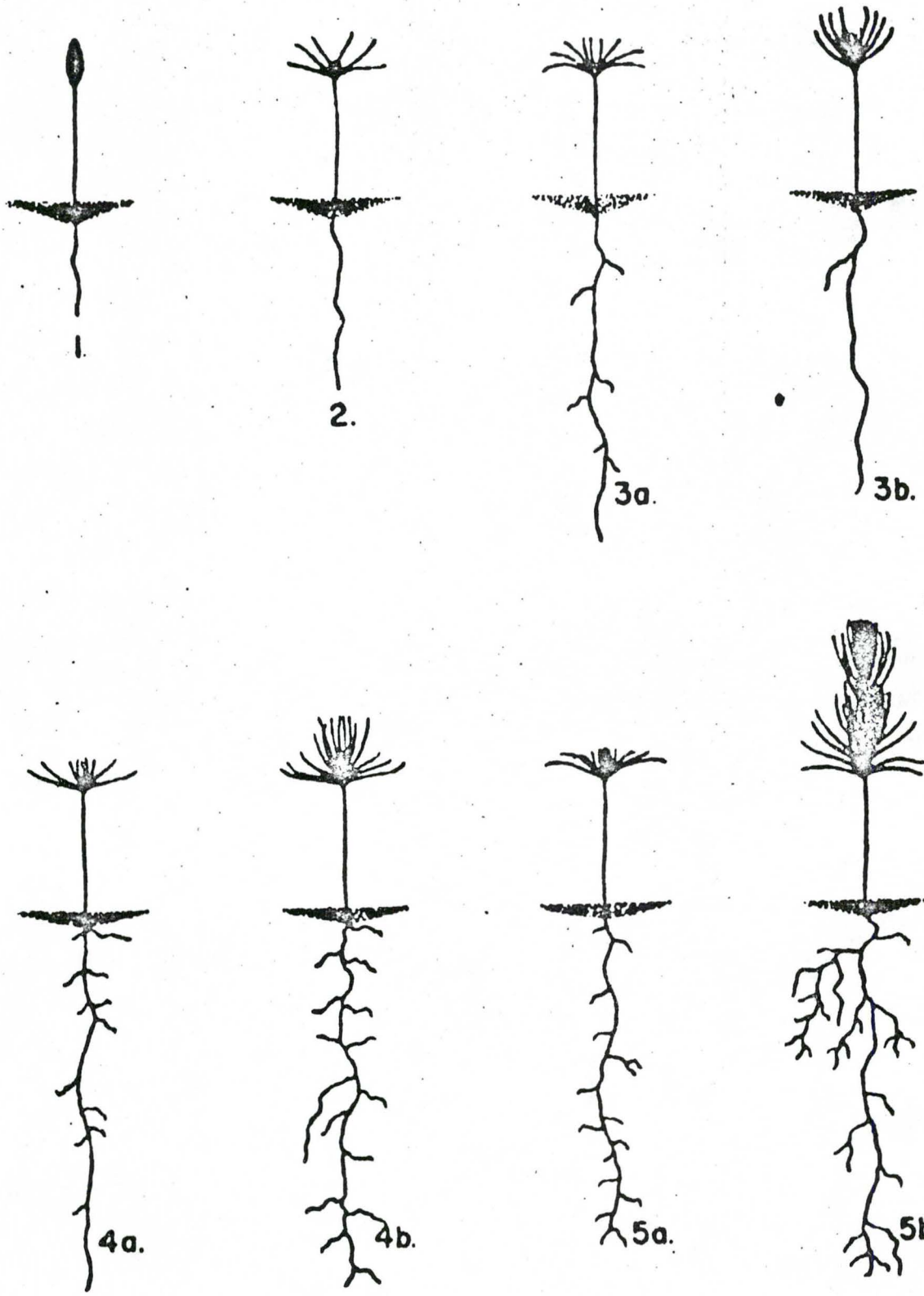


RED PINE

Stage of Development	Hardiness Characteristics
1. Seed coat adhering to cotyledons. Primary needles just visible. Stem greenish pink to pink. (Age up to 1 week.)	Seedlings subject to damping-off damage. Tissues very succulent, subject to drought, heat, frost and chill damage.
2. Seed coats thrown off. Primary needles up to ½ in. long. Stem pink. (Age 1 to 2 weeks.) Branch roots developing.	Damping-off not quite so likely. Still susceptible to drought, heat, frost and chilling.
3. Stem red to reddish brown. Secondary needles may start to develop. (Age 2 to 3 weeks.)	This is the first stage at which damping-off likely will not occur. Seedlings have considerable resistance to drought, heat, frost and chill injury.
4. Stem reddish brown to light brown, appearing wrinkled under hand lens. Secondary needles lengthen, if present. Secondary height growth may occur. (Age 3 to 5 weeks.)	Seedling well hardened, subject only to extremes of drought, heat and cold, except for succulent secondary growth.

WHITE SPRUCE

Stages of Development
(Grown in Greenhouse)

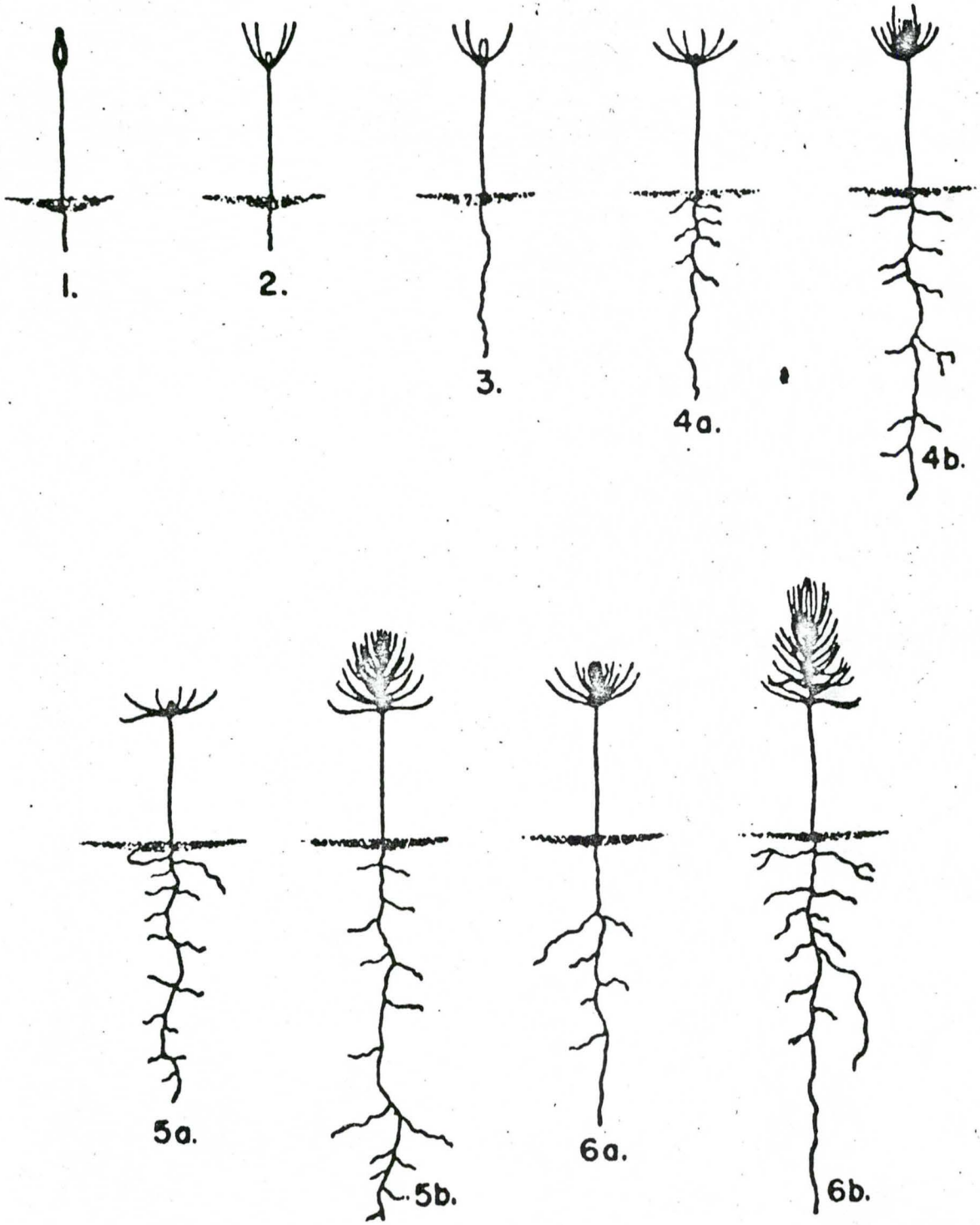


WHITE SPRUCE

Stage of Development	Hardiness Characteristics
1. Seedling with seed coat adhering to cotyledons. Primary needles just visible. Stem green. (Age up to 2 weeks.)	Seedlings subject to damping-off damage. Tissues very succulent, subject to drought, heat, frost and chill damage.
2. Seed coat thrown off. Primary needles easily seen, up to ½ in. long. Stem pale green to pinkish green, some reddish. (Age 1 to 3 weeks.)	Only slightly more hardy than in (1) above.
3. Stems pink to red - gradually turning light brown. Branch roots developing (Age 3 to 4 weeks.)	Essentially safe from damping-off.
3(a) Top growth arrested for at least several weeks. Terminal bud set-hardly visible at first. No secondary needles.	Fairly resistant to drought, heat, frost and chill injury.
3(b) Secondary needles develop with little delay. No obvious bud set.	Only moderately resistant to drought, heat, frost and chill injury.
4. Stems red to light brown. (Age 4 to 6 weeks.)	
4(a) Top development consists only of terminal bud enlargement.	Considerable resistance to drought, heat and cold. Seedlings are in a near-dormant state.
4(b) Top development consists of secondary needle growth and secondary height growth. Auxiliary buds sometime obvious as growth proceeds.	Considerable resistance to drought, heat and cold, except for succulent secondary growth.
5. Stems red or light brown; appear wrinkled under hand lens.	Seedlings well hardened, except for succulent secondary growth.
5(a) Bud flushes - secondary needles develop, height growth recommences and continues until dormancy. (Age 7+ weeks.)	
5(b) Height development continues until dormancy.	

BLACK SPRUCE

Stages of Development
(Grown in Greenhouse)



BLACK SPRUCE

Stage of Development	Hardiness Characteristics
1. Seedling with seed coat adhering to cotyledons. Primary needles just visible. Stem green. (Age up to 2 weeks.)	Seedlings subject to damping-off damage. Tissues very succulent, subject to drought, heat, frost and chill damage.
2. Seed coat thrown off. Primary needles easily seen, usually less than 1/8 in. long. Stem green. (Age 1 to 3 weeks.)	Only slightly more hardy than in (1) above.
3. As in (2), but stems vary from green to pale green to pinkish green. Primary needles up to ½ in. long. (Age 2 to 4 weeks.)	Damping-off may still occur. Only slight resistance to drought, heat, frost and chill injury.
4. Stems pink to reddish - gradually turning light brown. Branch roots developing. (Age 3 to 5 weeks.)	Essentially safe from damping-off.
4(a) Top growth arrested for at least several weeks. Terminal bud set - hardly visible at first. No secondary needles.	Fairly resistant to drought, heat, frost and chill injury.
4(b) Secondary needles developing with little delay. No obvious bud set.	Only moderately resistant to drought, heat, frost and chill injury.
5. Stems red to light brown appear wrinkled under hand lens. (Age 4 to 6 weeks.)	
5(a) Top development consists only of terminal bud enlargement.	Considerable resistance to drought, heat and cold. Seedlings are in a near-dormant state.
5(b) Top development consists of secondary needle growth and secondary height growth. Auxiliary buds sometime obvious as growth proceeds.	Considerable resistance to drought, heat and cold, except for succulent secondary growth.
6. Stems light brown.	Seedlings well hardened, except for succulent secondary growth.
6(a) Bud flushes - secondary needles develop. Height growth recommences and continues until dormancy. (Age 7+ weeks.)	
6(b) Height development continues until dormancy.	

Research Report No. 39 May 1959

ABSTRACT

EXPERIMENTAL PLANTING OF TUBED SEEDLINGS, 1958

M. M. McLean

Trials carried out in 1957 to assess the feasibility of planting tubed seedlings indicated that very young seedlings could survive under field conditions.

In 1958, a formal experiment was designed to determine whether this technique could be used during the summer months as well as the conventional planting seasons of spring and fall. Red pine was planted on a uniform site where a fire had recently occurred.

Late fall tallies in 1958 indicate that seedlings planted during the summer have satisfactory survival at the onset of winter.

Statistical tests indicate significant differences in survival percentage between fall and summer plantings and between screened and unscreened plots. In the latter case, differences were not due to protection against birds and animals, as was anticipated, but to changes in the seedlings' environment under screens.

Ontario Dept. of Lands & Forests
Division of Research

Research Report No. 52 Jan. 1964

ABSTRACT

PREPARATION AND PLANTING OF TUBED SEEDLINGS

V. H. H. Williamson

A developmental program was initiated in 1963 for the purpose of preparing tubed seedlings rapidly and in sufficient numbers for use in field plantings.

Special tubes, a machine to coat the tubes, devices to speed loading and seeding operations and a tool to aid in the planting of tubed seedlings were developed and tested with satisfactory results.

It is now possible for one man to prepare tubes, load them with soil, add seed, and place them in flats, ready for seed germination at the rate of 1200 per hour. When the seedlings are ready for planting one man can plant them at the rate of 300 per hour.

Ontario Dept. of Lands & Forests
Division of Research